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To cite this article: A Buynosov *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **918** 012151

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Organization of Repair of Locomotives on the Data of Monitoring Their Technical Condition

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Abstract. The article discusses the structure of the organization of current repairs of modern locomotives equipped with microprocessor control and diagnostic systems. Based on these systems, remote monitoring of the technical condition of locomotive units has been implemented. The block diagram of the recommendatory nature of the organization of current repairs using diagnostic information is presented. The above algorithm allows predicting the residual life by any of the studied parameters, thereby determining the mileage at the moment of which a failure occurs on some parameter. This gives a huge advantage in preventing incidents, as well as in the long-term planning of repair work on wheel turning and rolling, based on the remaining life. Thus, the well-coordinated organization of current repairs using diagnostic information, allows operational methods to eliminate the faults of the nodes. A recommender structure in the form of a single integrated system for organizing repair cycles will allow establishing links between the involved repair personnel in the form of electronic terminals for notification of the actual technical condition of the locomotive. A program has been developed for calculating the residual mileage of wheel sets for the corresponding types of defects, which also allows long-term planning for turning and rolling of wheel-motor blocks wheelsets, as well as to regulate the overhaul runs of a locomotive.

1. Introduction

Rail transport is highly relevant in Russia. Rail transport carries out half the freight turnover of our country [1, 2]. Based on transport and logistics needs and maintaining economic relations in the transport corridors of neighboring countries, the industry's locomotive fleet is replenished with modern locomotives that meet all international requirements and standards. The most striking example of modern representatives of freight traffic are the 2ES6 Sinara and 2ES10 Granit locomotives manufactured at the Uralsky Locomotives LLC plant, which is a joint venture of the Sinara Group and the Siemens Ag concern [3, 4].

Based on the specificity and complexity of the equipment of 2ES6, 2ES10 locomotives, the organization of a maintenance and repair system (MRO) needs to be developed both in terms of production capacities and in terms of automation and digitalization of technological processes. A significant role in the MRO system of the 2ES6, 2ES10 locomotives is played by the diagnostic information received from the on-board measuring equipment [5, 6]. All information received is sent to the Service Loco-



motive Depot Monitoring Center (SLD), where the specialists of this unit make management decisions on the further expedient operation of the locomotives, as well as inform service and repair personnel about violations in the operation of the units (Figure 1) [7, 8].

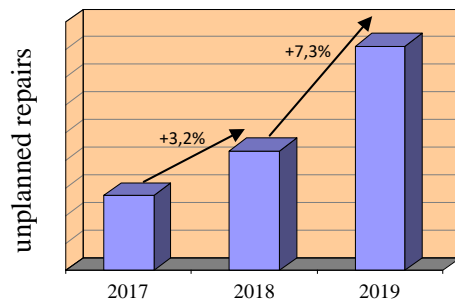


Figure 1. Statistics of unplanned repairs of 2ES6 Sinara locomotives, according to the Monitoring Center.

Increase in the number of unplanned repairs from 2017 to 2018, recorded by 3.2%, from 2018 to 2019, respectively 7.3% [9, 10]. It is possible to maintain high rates of unplanned repairs thanks to operational information from the SLD Monitoring Center, since a large number of incidents can be eliminated when electric locomotives enter equipment, second-level maintenance (TO-2), when entering the station, at the change point of locomotive crews. This increase in the rate of carrying out NR depended directly on the increase in the total average daily mileage of rolling stock units, changes in operating conditions, based on training ranges, professional competencies of both locomotive crews and repair personnel, and increase in train weight weights [11, 12].

The performance monitoring of the 2ES6 Sinara electric locomotive units is based on recording the values of electrical parameters, measuring equipment, individual sections of the power and auxiliary electric circuits of the locomotive [13]. The obtained measured values serve as primary information for the formation of diagnostic messages characterizing the signs of a malfunctioning state of nodes and assemblies of a locomotive [14, 15].

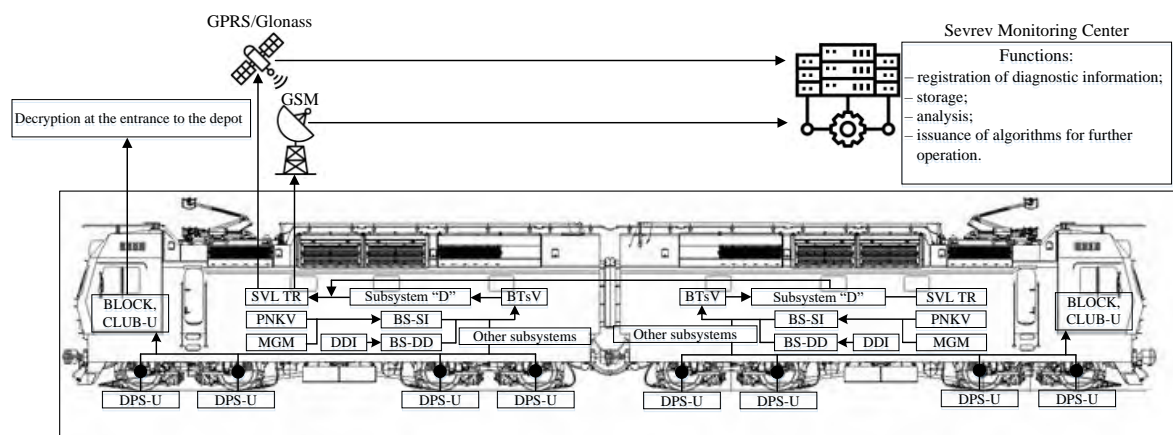


Figure 2. The algorithm for transmitting diagnostic information from the 2ES6 Sinara electric locomotive: GPRS / Glonass – an add-on over GSM mobile communication technology that performs packet data transfer; GSM – the global standard for digital mobile cellular communications; SVL TR – system of interaction with locomotives through technological radio communications; Subsystem “D” – a locomotive diagnostic subsystem; BTSV – block of the central computer; BS-SI – communication unit with measuring instruments; BS-DD – communication unit with pressure sensors; DDI – measuring pressure transducers; PNKV – voltage to code converters; MGM – insulation resistance meters; BLOCK – safe locomotive integrated complex; CLUB-U – unified integrated locomotive safety device; DPS-U – universal angle sensor.

The algorithm for transmitting diagnostic information (Figure 2) consists of recording the electrical parameters of individual parts of the power and auxiliary circuits of an electric locomotive, processing

the information in the BCV received from the measuring equipment (MGM, PNKV, DDI) and transmitting the processed information to subsystem D [16, 17]. All received volume data in subsystem D by software algorithms is converted into a kind of diagnostic messages that display deviations in the operation of individual nodes and parts of the locomotive, the converted information in messages are transmitted through the communication channel of the SVL TR to the Monitoring Centers [4, 18]. Information from safety devices (BLOCK, CLUB-U) is read and decrypted when a locomotive enters a depot or a locomotive maintenance point (PTOL).

The entire amount of diagnostic information received is subject to analysis for the correct operation of the corresponding equipment and is used as operational information for troubleshooting. A huge advantage should be considered diagnostic information, which signals latent defects that cannot be detected by organoleptic methods. There are also disadvantages associated with the inability to use the diagnostic information for the involved personnel during maintenance and repair, due to the multilevel approach to the maintenance concept of the maintenance and repair system [7, 19]. This implies the fact that the organization of maintenance and repair work is being developed as a single integrated organization system in carrying out repair cycles (Figure 3).

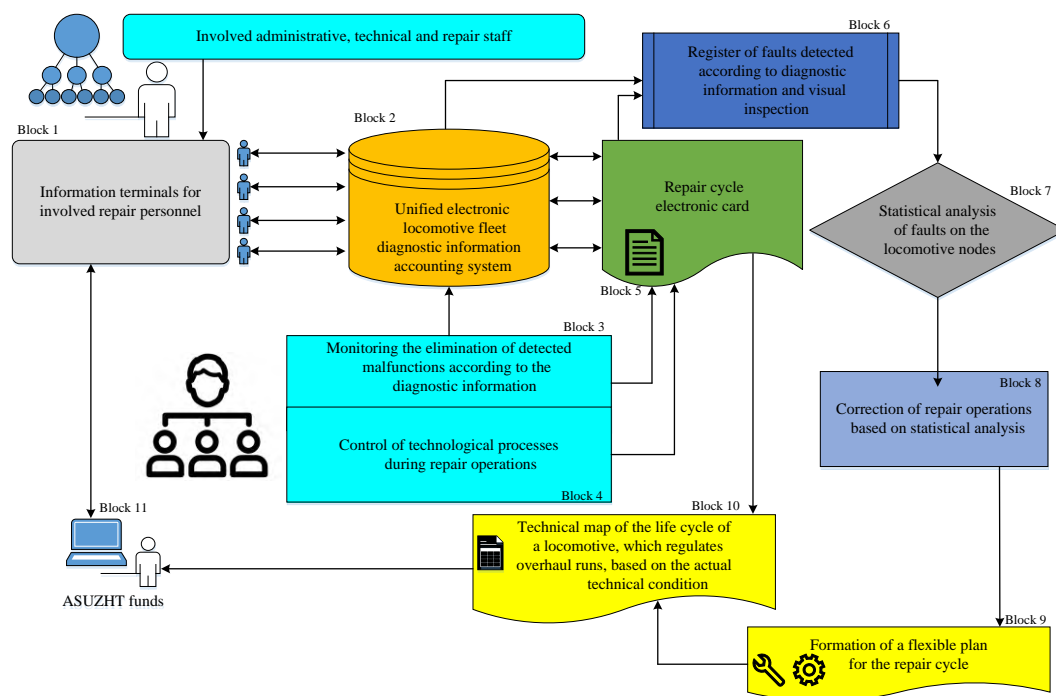


Figure 3. Unified integrated system for organizing the repair cycle of a locomotive.

The authors have developed a recommendatory structure for organizing the repair cycle of 2ES6 Sinara electric locomotives. The involved administrative, technical and repair personnel must be promptly and fully notified of the actual technical condition of the locomotive, according to diagnostic information, through the warning terminals (block 1). The entire amount of diagnostic information received from the Monitoring Center should be accumulated in a single electronic system for recording diagnostic information of the locomotive fleet (block 2), and broadcast to warning terminals (block 1). Block 3 implies an action aimed at eliminating malfunctions identified according to the diagnostic information, and adding this information to the electronic map of the repair cycle, similar to the paper form TU-28 (block 5). Block 4 implies the fulfillment of all points of the technological maps of the repair cycle, as well as the reporting in block 5. All the information collected about the detected malfunctions during the repair is sent to the register of detected malfunctions (block 6).

SLD technology groups, the accumulated information is subjected to statistical analysis to identify weaknesses of locomotive nodes and to develop corrective repair measures aimed at improving the

reliability of these nodes (block 7). Block 8 implies actions aimed at adjusting technological processes, according to statistical analysis, for the development of technical measures for the differentiation of overhaul runs of electric locomotives, based on the actual technical condition. Based on the results of block 8, a flexible plan for carrying out repair cycles is formed taking into account the previous type of repair, diagnostic information, reliability analysis of SLD technology groups, prediction of the residual resource of nodes most susceptible to disruption in performance. All information from block 5 and block 9 is collected into a single map of the life cycle of the locomotive, which regulates overhaul runs, based on the actual technical condition and prediction of the residual life (block 10). The life-cycle map of a locomotive is reflected in the means of an automated railway transport management system (ASUZHT), for operational control of the involved administrative staff (block 11).

2. Experimental Data and Results

Following the statistics of unscheduled repairs to Sinara 2ES6 series electric locomotives, a significant part of the repairs is taken by TO-4 cycles and rolling of wheel-motor blocks, due to defects in wheel sets (Figure 4).

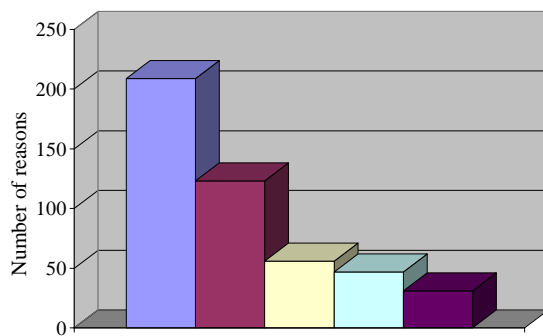


Figure 4. Statistics of the reasons for unplanned repairs on wheelsets of 2ES6 electric locomotives for 2019: ■ – the thickening of the rowing bandage; ■ – thickness of the bandage; ■ – slider, pothole on the surface of the skating; ■ – peaked roll crest bandage; ■ – the steepness of the crest of the bandage.

Analysis of the statistics of the reasons for unplanned repairs on wheelsets of 2ES6 electric locomotives (Figure 4) shows that the actual problem of wear of bandages and ridges still remains unresolved [6]. Lubrication systems, hardening systems do not help to achieve high performance in running hours, so the urgent task is to determine the residual life of the wheelsets for the rapid detection and elimination of defects [20].

The authors developed a program, written in Python, for calculating the residual life of the limiting components of an electric locomotive, in which there is the possibility of calculating and determining the residual mileage of the wheelset according to one of three parameters: the thickness of the band ridge, the thickness of the band, the steepness of the band ridge, and also obtained a patent for utility model [7].

The calculation is based on the least squares algorithm [8]. The least squares method is a mathematical method based on minimizing the sum of the squares of the deviations of some functions from the desired variables. The method allows you to approximate the data by the linear dependence $y = a \cdot x + b$. Finding the parameters a and b will allow us to determine the position of the curve and determine the intersection point with critical values for each parameter, in order to find the value at which moment the limit value of wear will be fixed. The values of the variables y and x will be the value of wear and mileage of the wheelset, respectively. The calculation of the data array, in order to find the parameters a and b , is carried out according to the following formulas [8]:

$$a = \frac{\sum_{i=1}^n (y \cdot x) - (\sum_{i=1}^n x \cdot \sum_{i=1}^n y) / n}{\sum_{i=1}^n x^2 - (\sum_{i=1}^n x)^2 / n}, \quad (1)$$

$$b = \frac{\sum_{i=1}^n y}{n} - \frac{a \cdot \sum_{i=1}^n x}{n}, \quad (2)$$

where y is the parameter wear value, mm; x is the value of the run, the studied period, km; n is the number of studies, units.

The construction of lines is carried out according to the found coefficients a and b for each studied parameter (Figure 5).

From Figure 5 shows that the dialog box is divided into two subwindows. In one, all measurements of the wheelset parameters are affixed, and in the other, graphs characterizing the residual resource are displayed. Residual resource results are also written. Each corresponding line for each parameter has a corresponding color and shows the slope, that is, it shows the point of intersection of these lines with critical values for each type of defect, thereby determining the mileage at the moment of which there will be a need for organizing unscheduled repairs or elimination during the planned setting. In Figure 6 presents the calculation algorithm embedded in the program.

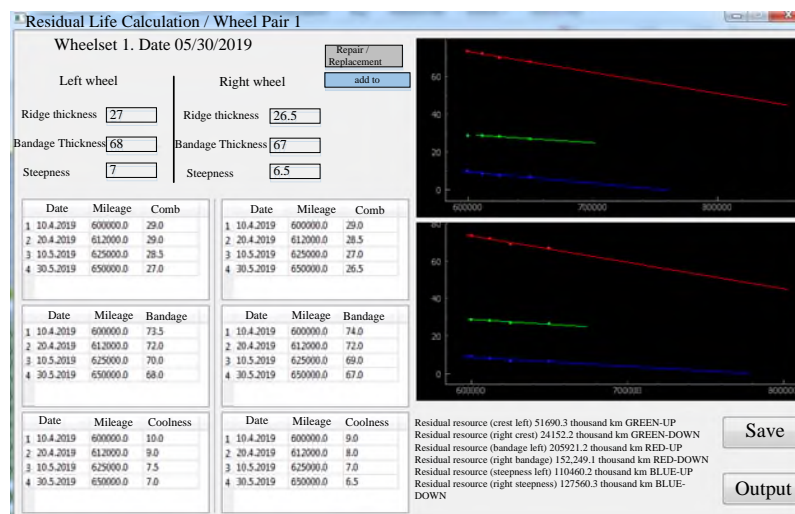


Figure 5. Dialog box of the program for entering values of parameters of wheelsets, displaying graphs and values of residual life.

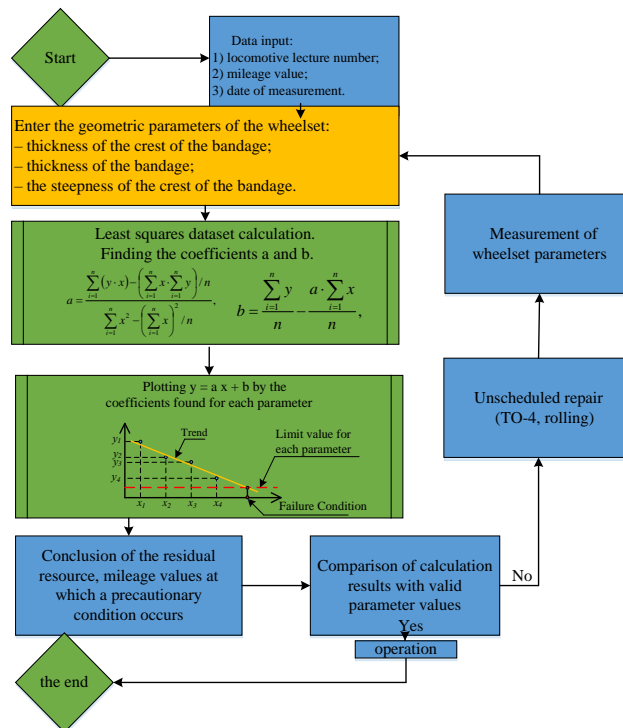


Figure 6. Algorithm for calculating the residual mileage of wheelsets for corresponding defects.

3. Conclusions

1 This algorithm makes it possible to predict the residual life by any of the studied parameters, thereby determining the mileage at the moment of which a failure occurs on any parameter. This gives a huge advantage in preventing incidents, as well as in the long-term planning of repair work on wheel turning and rolling, based on the remaining life.

2 The organization of current repairs using diagnostic information allows operational methods to eliminate the faults of the nodes.

3 The recommendation structure in the form of a single integrated system of organization of repair cycles (Figure 3) will allow to establish communications between the involved repair personnel in the form of electronic terminals to alert about the actual technical condition of the locomotive.

4 The use of the developed program in the organization of the current repair system for calculating the residual life of wheelsets, according to the corresponding defects, will allow long-term planning of repair cycles for wheelsets, as well as regulating the overhaul runs of a locomotive.

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